

Contract No. G-017-037
“Improved Directional Drilling Technology for the Bakken Formation”
Submitted by **Laserlith Corporation**
Principal Investigator: Wallace Tang

PARTICIPANTS

Sponsor	Cost Share
Laserlith Corporation	\$200,000
North Dakota Industrial Commission	<u>\$200,000</u>
Total Project Cost	\$400,000

Project Schedule – 12 months
Contract Date – June 22, 2009
Start Date – June 1, 2009
Completion Date – February 28, 2011

Project Deliverables:
Status Report: September 30, 2009 ✓
Status Report: December 31, 2009 ✓
Status Report: March 31, 2010 ✓
Draft Final Report: June 30, 2010 ✓
Final Report: February 28, 2011 ✓

OBJECTIVE/STATEMENT OF WORK:

The objective of this project as originally submitted is to increase the efficiencies of horizontal drilling in the Bakken Formation through a redesign of drilling tools by including the use of miniature gyroscopes in the drilling assemblage. The result of the project will be a prototype miniature MEMS gyroscope demonstrated at temperature typical in the drilling environment. High-temperature shock-resistant MEMS gyroscopes enable the directional sensor to be positioned next to the drill bit, resulting in a reduction of backtracking, more accurate navigation and time-savings. The original request from Laserlith was for \$500,000. The Commission funded only Phase I of the project. The goal for Phase I is to develop the micromechanical sensing element, select the specialized high temperature semiconductor foundry and design the sensor circuit. The deliverable for the 1-year Phase I project is the test data demonstrating the ability of the micromechanical sensor to operate in the simulated down-hole temperatures.

STATUS

The September 30, 2009 quarterly report was received. A copy of the non-confidential report has been posted on the Industrial Commission website. It states in part: “The main focus of the last quarter was to design a basic MEMS gyroscope and perform temperature sensitivity analysis on it to study the effects of temperature. FEA modelers were used to study thermal-structural interactions for fixed-fixed flexure structures and simplified gyroscope frames.

In the first simulation, the fixed-fixed flexure, one of the basic and critical parts of the gyro was studied. This was performed for temperatures ranging from 0 to 200 degrees C. The maximum displacement observed is a 0.6% deflection of the total thickness of the structure.

As each study confirmed thermal compatibility, the next level of complexity was added to create a more realistic representation of the actual gyro. The same input parameters for the simulation were used. The results showed that the beams had made less out-of-plane deformation (maximum of 0.1%) along its length. Structural deformation of the device layer is reduced since the substrate will expand along with the flexure as opposed to the last study where the anchors were fixed.

The next step toward demonstrating the thermal robustness of the MEMS gyroscope design was to include a full structure simulation at a temperature of 200 degrees C. The total deformation at this temperature was considered negligible. All of these results confirm that the thermal effects the gyro would encounter in a drilling environment will not affect its performance.”

The December 31, 2009 quarterly report was received. A copy of the non-confidential portion of the report has been posted on the Industrial Commission website. During the past quarter the high temperature gyroscope designs were completed. Computer simulation results indicate that the gyro sensor design will not buckle under the harsh thermal conditions and should operate successfully. An initial MEMS fabrication run was also performed to produce MEMS test structures within design specifications for linewidth and sidewall quality. An initial circuit design has been developed for driving the gyroscopes and sensing changes in capacitance in the range of picofarads.

The March 31, 2010 quarterly report was received. A copy of the non-confidential portion of the report has been posted on the Industrial Commission website. During the past quarter additional testing and process development of gyroscopes from the initial MEMS fabrication run were completed. This work includes testing the electrical properties and the mounting and packaging of the sensor. Data gathering from testing has aided in adjusting the design for the upcoming fabrication run. The control circuit design was completed and is currently being fabricated. A vacuum test chamber for the gyroscope has been built which will be used to create a test setting typical of a drilling environment.

An amendment was executed on this contract establishing the date for submission of a draft final report and then the date of the final report submission.

The June 30, 2010 draft final report was received.

The final report dated February 28, 2011 was received. A copy of the non-confidential portion of the report has been posted on the Industrial Commission/Oil and Gas Research Program website. The Final Project Summary states:

It is imperative to bring reliable, domestic hydrocarbon reserves on-stream to help the United States reduce dependency on foreign oil. Hence, the Bakken Formation, with estimated reserves at 200-400 billion barrels of oil, is a critical national asset that needs to be developed to its maximum capacity. At presently only 1% - 3% of Bakken reserves are anticipated to be recovered due in part to limitations with existing oilfield technology, including limitations in the accuracy of existing directional drilling technologies. The current technology, magnetometers, cannot be significantly improved since the errors are introduced by external sources.

Gyroscopes are inertial sensors that measure rate of rotation (in %/sec or %/hr) without reference to external coordinates. MEMS vibratory gyroscopes are based on Coriolis acceleration, which arises in a rotating frame of reference and is proportional to the rate of rotation. The gyroscope is forced to vibrate (typically using inter-digitated comb drives) in the sense axis at its characteristic resonant frequency. When subjected to angular rotation, the vibrating mass feels Coriolis acceleration in the direction orthogonal to the drive direction and axis of rotation. This motion in the sense direction is directly proportional to the rate of rotation and is typically measured using capacitive sensing.

The intent of this project is to increase the efficiency of horizontal drilling in the Bakken Formation by including the use of miniature gyroscopes in the drilling assemblage. The result of the project will be a prototype miniature MEMS gyroscope demonstrated at temperatures typical in the drilling environment. In particular, high-temperature shock-resistant MEMS gyroscopes enable the directional sensor to be positioned next to the drill bit, resulting in more accurate navigation, and reduction in drilling cost and time.

The project started with a basic MEMS gyroscope design to perform temperature sensitivity analysis and to study the effects of the high temperature typically encountered in the down-hole environment. FEA modelers were used to study thermal-structural interactions and model response at a temperature of 200°C. The results were used to develop an optimized gyro for the requirements set by the end user. The resulting final design provides a multi-fold sensitivity increase, as compared to the initial gyroscope design. Two iterations of MEMS gyroscope processing have been completed.

A closed-loop control circuit was developed and is responsible for oscillating the gyroscope's drive mass while simultaneously detecting any movement from the sense mass. The circuit outputs a signal proportional to the rotation rate sensed by the gyro. It must be able to detect small capacitance changes in the sense combs, correct for errors such as quadrature and the Coriolis offset, and keep any electrical noise to an absolute minimum.

A custom test chamber was built that can be heated up to 200°C simulating the drilling environment. The test vacuum chamber has feedthroughs to connect a power supply and receive signals from the sensor. It will be connected to a vacuum pump to reach UHV levels and mounted to a motor capable of rotating at a rate of 0.25°/min.

The operation of the control circuit and the gyroscope has been verified. The signal from the mechanical sensing element has demonstrated features typical of an operating gyro. Approximately 75% of the test effort is completed. The next step will be to test the gyro in the vacuum test chamber and then measure performance in a high temperature environment.

Laserlith Corporation has submitted an application to the Oil and Gas Research Program for additional funding for the next phase of the work to improve directional drilling technology.

06/29/11